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ASTANA, KAZAKHSTAN

A Full-Year Study

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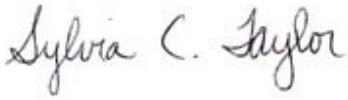

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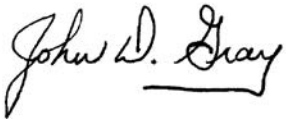

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14. ABSTRACT

This country climatology digest is a climatological study of Astana, Kazakhstan. After describing the geography and major meteorological features of the entire region, the study discusses in detail the climatic controls of Astana's weather. Each "season" is defined and discussed in considerable detail with emphasis on general weather, hazards, clouds, visibility, winds, precipitation and temperature.

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CONVENTIONS. The spelling of place names and geographical features are those used by the National Geospatial-Intelligence Agency (NGA). All distances are in nautical miles (NM) and kilometers (km), except for visibility, which is in statute miles and meters. Elevations are in feet above mean sea level (MSL), with a metric equivalent following. Temperatures are in degrees Fahrenheit (F) and Celsius (C). Wind speeds are in knots. Cloud bases are above ground level (AGL) unless otherwise stated; tops, when provided, are above mean sea level. Precipitation amounts are in inches, with millimeter (mm) or centimeter (cm) equivalent following them. Precipitation values given are liquid equivalents unless stated otherwise. Any graphics provided to supplement the text will not include metric equivalents. Additionally, data shown in graphics for specific locations do not always represent overall conditions in complex terrain. Standard pressure levels are expressed in millibars (mb). Time is reported either in Coordinated Universal Time (UTC) (also known as Zulu or Z), or Local (L).

TERRAIN. Astana, formerly Akmola or Aqmola, is the capital city of Kazakhstan and of its province, Aqmola. Astana has been known by several names in its history. Established as a fortress in 1824, it has also been named Akmolinsk, Tselinograd and Celinograd. All of these names appear on modern maps. Astana (means capital) is in north central Kazakhstan on the banks of the Ishim River (also seen as the Esil River). Astana is an important junction on the famous Trans-Siberian Railroad (HighBeam Encyclopedia, 2006, wikipedia, 2006). Figure 1 is an excerpt from Joint Operations Graphic NM 42-3. Elevations are reported in meters. Figure 2 is an excerpt from a NASA satellite image taken on September 20, 2002.

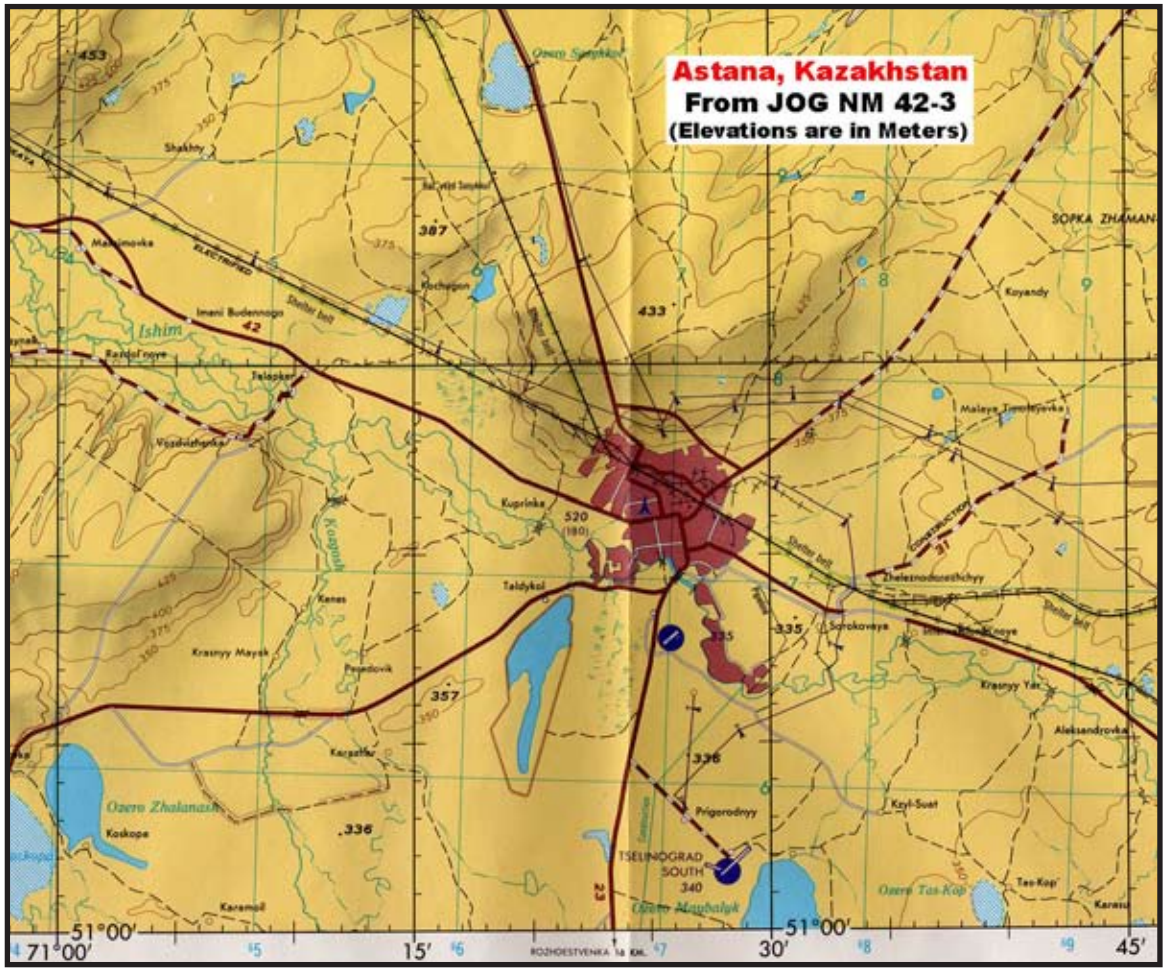

Figure 1. Excerpt from Joint Operations Graphic NM 42-3.

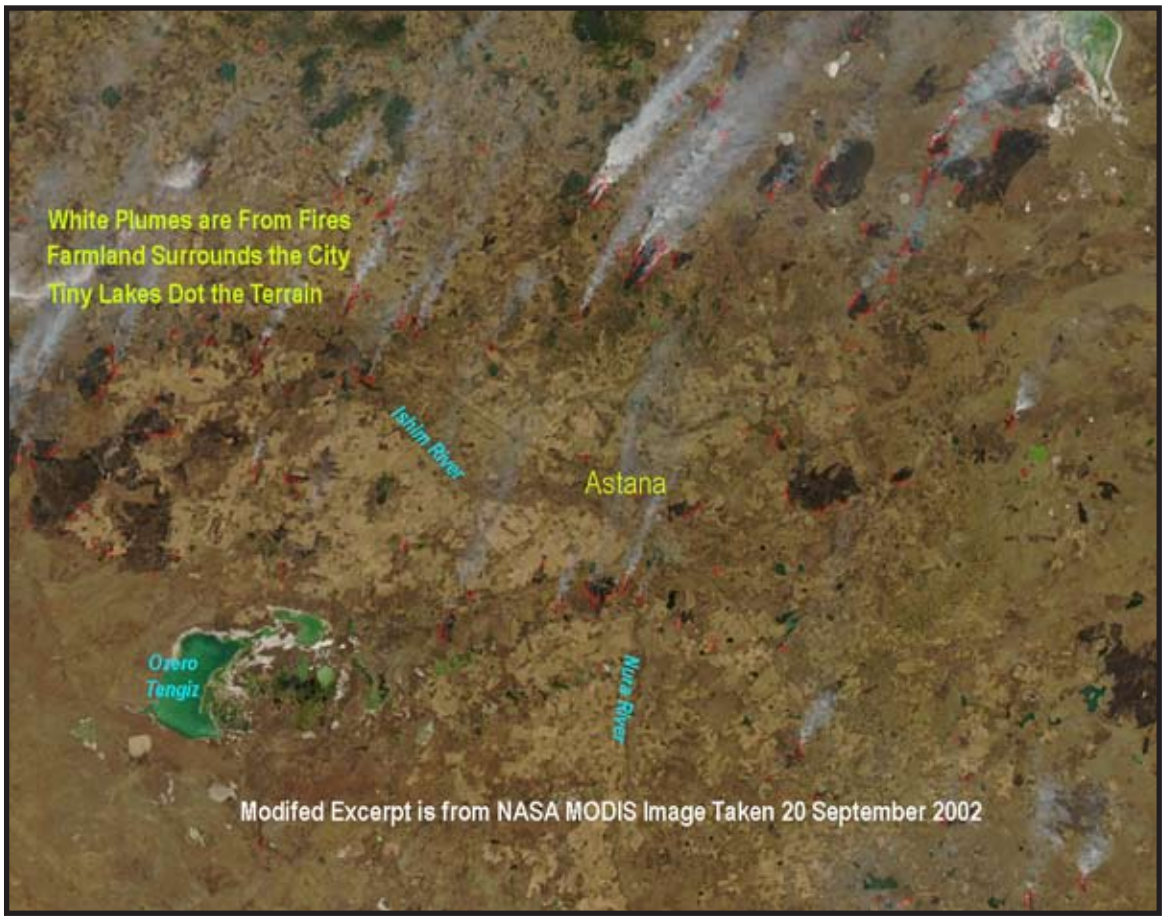

Figure 2. NASA Satellite Image taken on September 20, 2002.

Astana is on the northern central plain of Kazakhstan just south of the Russian border. The Kazakh Hills are just to the east and a low hilly ridgeline is to the west, south of the Ishim River. The Kazakh Hills, also seen as the Kazakh Uplands, is an ancient, deeply eroded mountain range that extends from the northeastern rim of Lake Balkash far to the southeast northwestward to the eastern end of the Ishim River and eastward to the mountains of easternmost Kazakhstan. Astana is in a shallow basin with terrain that rises gently around it. Elevations in the Astana area average 985 to 1,150 feet (300 to 350 meters). The higher terrain in the immediate area averages 1,315 to 1,640 feet (400 to 500 meters). Shelter belts (lines of trees) to the northwest through northeast and again to the east, protect the city from the powerful winter winds that flow into Kazakhstan out of the Siberian plains.

The Ishim River is a tributary of the Irtysh River. It rises in the Kazakh Hills and meanders westward in two or more braided channels before it turns northward to eventually meet the Irtysh in the Russian steppes (HighBeam Encyclopedia, 2006). Several minor rivers and streams feed the Ishim from both the north and the south. The Kozgosh is one of the larger tributaries in the Astana area, and it joins the Ishim from the south. As do other minor streams, the Kozgosh branches off from the Nura River, which empties into Ozero Tergiz (Ozero means lake) southwest of Astana. There are marshy areas just to the northwest and to the south of Astana and a reservoir to the southwest. A number of small lakes dot the area. Some are seasonal and contain water only in summer, but most are permanent. All local lakes and rivers freeze in winter, typically by mid November (Higdon, 2002, NIS 26, 1973). Figure 3 is a terrain map of Kazakhstan. Figure 4 shows the provinces of Kazakhstan.

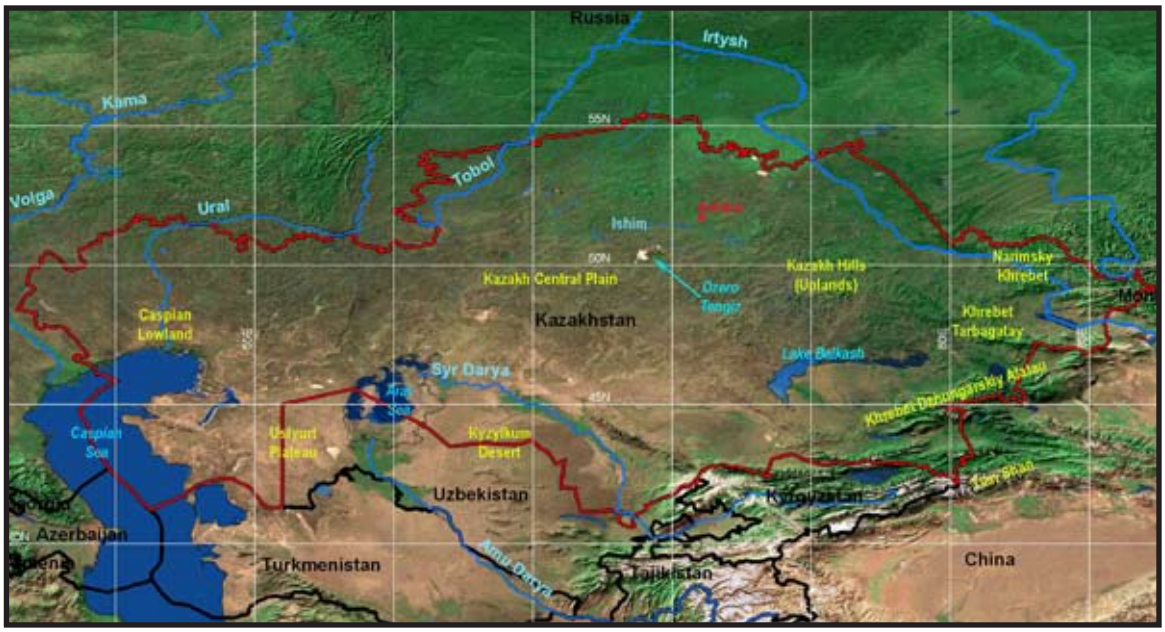

Figure 3. Kazakhstan Terrain Map.

Figure 4. Provinces of Kazakhstan.

WINTER (DECEMBER-MARCH)

General Weather. Astana has a continental climate dominated by two large, semi-permanent pressure systems; the Asiatic high (winter) and the Asiatic low (summer). The Asiatic high is a large, cold thermal pressure system with a mean center over western Mongolia. It is the dominant climatic control in the region in winter. In January, the Asiatic high expands its influence westward into Europe and eastward into far eastern Siberia. The Asiatic high is shallow, and its position and strength fluctuate periodically. It begins to form in September and is in place by the middle of October. It is at peak strength from late December through February and disappears by May (Freeman, et al, 2000, Landsberg, 1974, NIS 26, 1973). Figure 5 shows the mean sea-level pressure and wind flow for January. Figure 6 shows the source regions for air masses that reach the Astana area.

Migratory lows and highs affect the area. While lows do not pass through this region on a regular basis, their fronts or wrap-around cloud cover and precipitation can affect the weather. Higher frequencies of low ceilings and visibility occur in late fall through early spring when low-pressure (storm) system activity is at its peak. These cyclones form in 3 main regions; the Mediterranean and Black Seas, the North Atlantic Ocean and Mongolia (Freeman, et al, 2000, Landsberg, 1974, NIS 26, 1973).

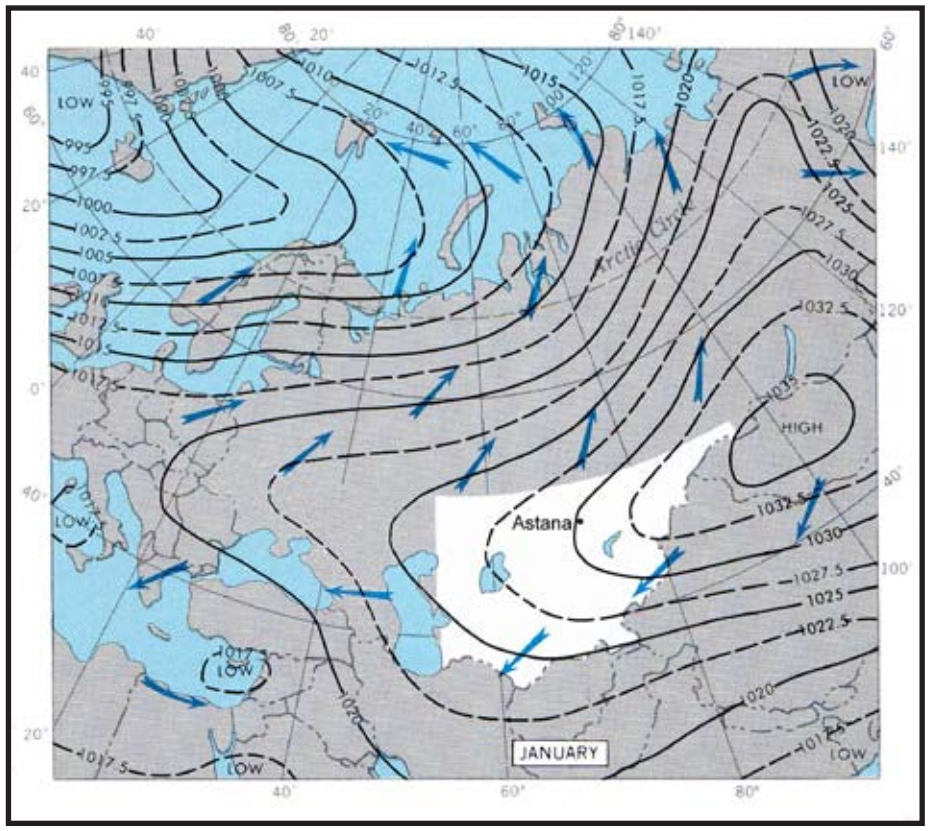

Figure 5. January Mean Sea-Level Pressure and Generalized Wind Flow.

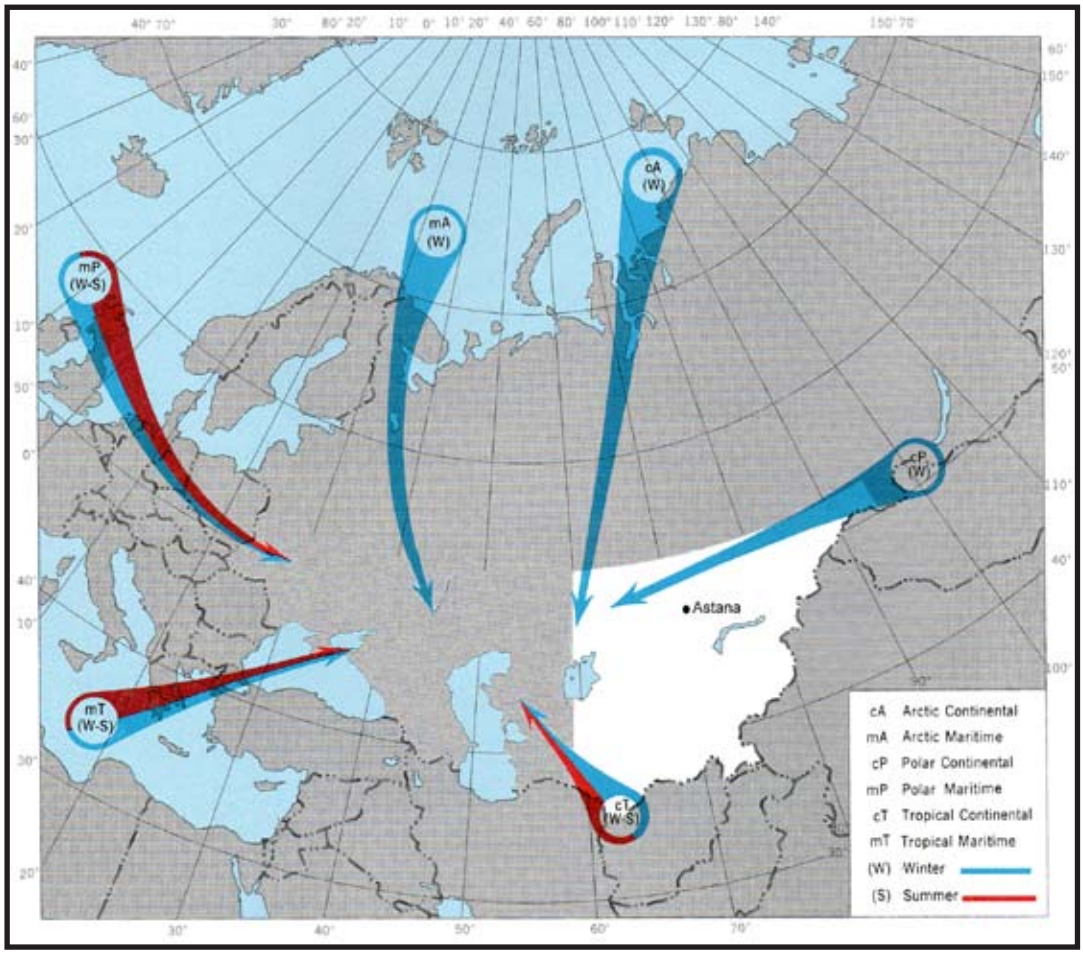

Figure 6. Air Mass Source Regions.

From November through March, lows from the Mediterranean and Black Seas reach Astana most often. Lows will occasionally form over the southern end of the Caspian Sea in early and late winter. These lows normally miss the region as they pass by to the north or south. The storm track depends on upper flow patterns and the relative strength of the Asiatic high. Much of the precipitation that falls in November-March is with these lows. If the centers move west to northwest of the area, Astana will have weather ahead of and with cold fronts for 3-9 hours. Lows that track south of the area usually have occluded fronts. These cause 1-3 days of low cloudiness, reduced visibility, and snow showers (Freeman, et al, 2000, Landsberg, 1974, NIS 26, 1973).

Lows from the North Atlantic and northern Europe travel across Central Asia and Russia year-round. These lows stay north of the Astana area, but their fronts and winds can affect the weather. Strong, shifting winds, brief periods of overcast, and showers (rain or snow) accompany these fronts. Migratory highs affect the area throughout the year. These highs originate mainly in three regions. Highs that split off the Azores high move in from the west to northwest in winter. Mild, moist air with these highs can bring considerable low cloudiness as it moves over the cold ground. Arctic highs move in from the north and northeast throughout the year, most often in winter. These highs are very cold and dry. Strong winds can occur when these highs first move in behind cold fronts. Cold fronts are the most common weather systems to affect the area in winter. Snow, gusty winds, and much colder temperatures occur behind winter cold fronts. Warm fronts affect the area during the winter and occur with lows that move southwest to northeast near the area. They normally produce light, steady precipitation (Freeman, et al, 2000, Landsberg, 1974, NIS 26, 1973). Figure 7 shows the December through February storm tracks.

The Asiatic high is a source of migratory highs. These highs break away from the main center and move westward into the area. The Asiatic high itself occasionally ridges westward to cover the area. Cold, dry, stable air accompanies these systems. Strong, persistent low-level inversions occur when the Asiatic high ridges over the area. These inversions trap moisture and pollution, which can lower visibility for days at a time. The shallow basin in which Astana is built contributes to that problem as a relatively low spot where cold air pools. This intensifies low-level inversions and caps circulation of the air (Freeman, et al, 2000, Landsberg, 1974, NIS 26, 1973).

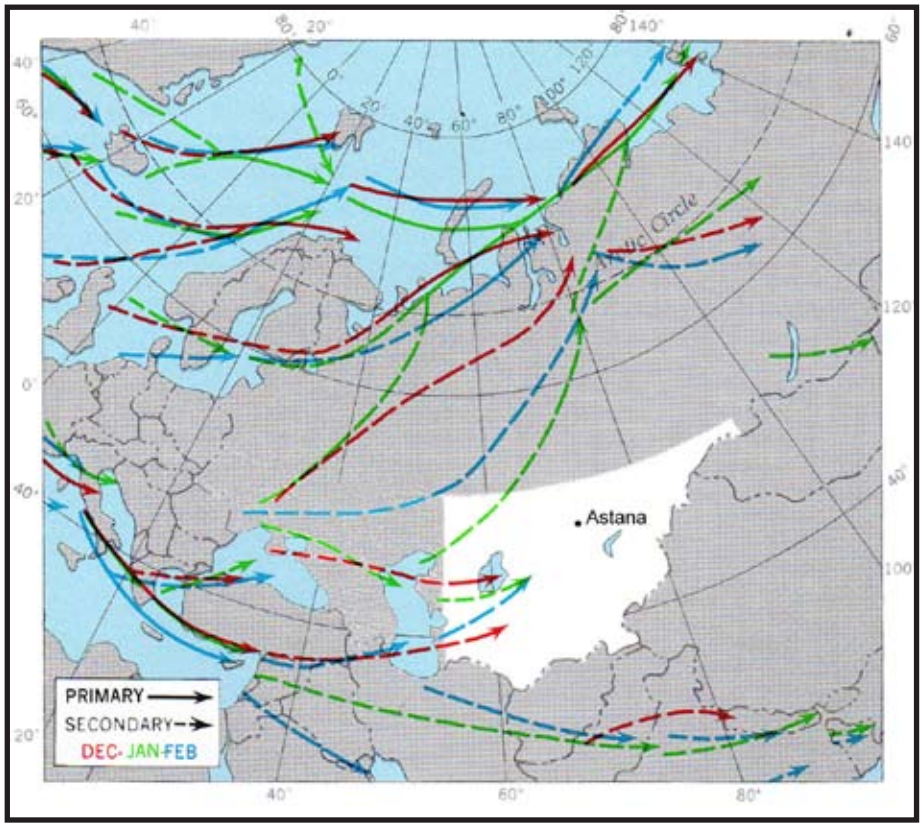

Figure 7. Storm Tracks for December through February.

Sky Cover. The mean cloud cover is broken all winter at Astana. Stable cloud forms are the most common and multi-layered clouds from low stratus all the way to high cirrus are typical of passing storms, especially when storms pass by to the south close enough to advect wrap-around clouds over Astana. Overcast conditions occur ahead of and with passing storm systems and clear skies occur under strong highs and behind cold fronts. Although totally cloudless days are few, periods without ceilings occur an average of 35 to 40 percent of the time. Table 1 shows the percent frequency of occurrence of ceilings at specified levels and times for the full year.

Table 1. Percent Frequency of Occurrence of Ceilings at Specified Levels and Times.

Astana, Kazakhstan

Ceilings Less Than 25,000 feet

HR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
00-02L	56	47	44	35	29	30	33	30	32	47	58	61
03-05L	58	51	51	36	31	29	30	28	32	46	61	61
06-08L	61	52	54	42	40	36	40	40	39	51	62	61
09-11L	62	57	55	44	39	35	39	38	42	56	66	67
12-14L	57	50	50	49	48	47	54	48	48	59	64	61
15-17L	55	48	50	51	51	52	59	54	50	58	63	60
18-20L	55	44	45	47	50	49	54	49	47	52	59	57
21-23L	53	41	41	38	41	42	44	38	36	43	56	59

Ceilings Less Than 10,000 feet

HR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
00-02L	52	43	41	30	25	25	27	26	30	43	56	56
03-05L	54	47	49	32	27	25	25	24	29	44	57	57
06-08L	58	48	50	36	34	29	34	34	35	47	59	56
09-11L	59	53	49	35	30	26	31	33	35	51	62	62
12-14L	50	41	42	40	39	38	47	41	40	53	59	55
15-17L	46	40	40	41	44	44	52	47	43	50	57	53
18-20L	50	37	37	39	41	41	44	41	39	46	55	50
21-23L	49	37	37	32	35	33	33	33	32	40	54	54

Ceilings Less Than 3,000 feet

HR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
00-02L	39	31	32	18	11	10	11	10	13	25	44	44
03-05L	40	34	39	20	13	10	11	11	13	26	46	46
06-08L	45	34	40	22	18	14	14	18	17	29	49	46
09-11L	46	38	38	25	16	11	15	15	18	30	51	49
12-14L	34	27	33	24	20	15	20	20	19	34	46	40
15-17L	31	26	31	24	23	22	26	23	21	32	43	39
18-20L	34	24	28	24	23	20	20	17	18	27	41	38
21-23L	36	25	28	17	15	13	14	13	13	25	42	41

Ceilings Less Than 1,000 feet

HR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
00-02L	15	13	15	6	2	1	1	1	1	4	18	19
03-05L	16	16	19	8	2	1	2	2	2	6	20	21
06-08L	18	15	23	9	4	3	3	5	4	8	23	20
09-11L	20	20	21	11	3	1	2	3	6	9	25	23
12-14L	13	10	16	5	2	0	1	1	2	7	18	18
15-17L	11	10	11	3	1	0	0	0	1	5	14	17
18-20L	12	8	11	4	1	1	0	0	1	6	13	16
21-23L	12	11	12	4	2	1	0	1	1	6	16	17

Ceilings Less Than 200 feet

HR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
00-02L	1	1	2	1	0	0	0	0	0	0	2	2
03-05L	2	2	3	1	0	0	0	0	1	0	2	2
06-08L	2	2	4	1	0	1	0	0	0	1	2	2
09-11L	1	2	3	1	0	0	0	0	0	1	3	2
12-14L	0	1	0	0	0	0	0	0	0	0	1	1
15-17L	0	1	0	0	0	0	0	0	0	0	0	0
18-20L	0	0	1	0	0	0	0	0	0	0	1	1
21-23L	1	1	1	0	0	0	0	0	0	1	2	1

Visibility. Snow and blowing snow are typical causes of restrictions to visibility in winter. Falling and blowing snow account for 45 to 50 percent of occurrences of visibility below 7 miles (11,000 meters) in December through February and 30 to 35 percent of them in March. Fog accounts for 10 to 15 percent of restrictions. Ice fog is a problem around airfields, industrial plants and population centers, especially in late December through February, when extremely cold temperatures occur often. Very poor visibility is usually due to snow. Blowing dust can occur in the region but is rare and does not typically restrict visibility very much because of the vegetation in the area. Plowed fields are the local dust sources. Table 2a shows the percent frequency of occurrence for visibility at defined restrictions and times for the full year. Table 2b shows the percent of time visibility is restricted to defined levels by specified criteria for the full year. As shown in the table: if visibility is restricted below 11,000 meters in January, smoke is the cause 13 percent of the time and snow is the cause 50 percent of the time.

Table 2a. Percent Frequency of Occurrence for Visibility at Defined Restrictions and Times.

Astana, Kazakhstan

Visibility Less Than 7 miles (11,000 meters)

HR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
00-02L	64	65	64	59	49	43	44	45	49	49	48	62
03-05L	63	70	67	60	51	47	44	46	51	49	52	59
06-08L	60	65	68	51	29	24	23	26	47	46	52	55
09-11L	62	67	64	46	28	27	25	32	39	43	51	56
12-14L	62	62	51	35	23	21	17	23	29	35	47	57
15-17L	54	52	42	31	22	20	17	21	24	29	40	49
18-20L	56	49	41	31	21	20	16	21	24	31	44	57
21-23L	62	67	62	55	31	22	22	31	54	50	51	65

Visibility Less Than 3 miles (4,800 meters)

HR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
00-02L	24	22	18	8	4	1	1	1	3	6	14	23
03-05L	26	23	22	10	4	2	2	2	4	7	15	20
06-08L	26	24	25	12	3	2	4	5	5	9	16	21
09-11L	27	30	27	11	2	1	3	3	7	12	21	23
12-14L	27	23	18	5	1	1	1	2	2	7	18	22
15-17L	19	16	11	3	1	1	1	1	1	5	12	16
18-20L	19	15	10	4	1	1	1	1	1	6	15	20
21-23L	24	23	14	7	2	1	1	2	5	9	15	25

Visibility Less Than 2 miles (3,200 meters)

HR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
00-02L	17	16	11	5	2	1	1	1	2	4	9	15
03-05L	17	17	15	6	2	1	1	1	2	4	10	15
06-08L	18	17	17	7	1	1	1	2	3	6	12	16
09-11L	16	18	14	5	1	1	1	1	2	5	11	13
12-14L	11	10	5	2	0	0	0	0	0	2	8	9
15-17L	8	8	3	1	1	0	0	0	0	2	6	7
18-20L	10	7	4	1	1	0	0	0	0	2	6	9
21-23L	16	14	8	2	0	1	1	0	2	6	10	15

Visibility Less Than 1 mile (1,600 meters)

HR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
00-02L	9	9	6	2	1	1	0	1	1	1	5	8
03-05L	9	10	10	3	1	1	0	0	2	2	6	9
06-08L	9	9	12	4	1	0	1	1	3	3	6	9
09-11L	7	8	7	3	1	0	0	0	1	2	6	6
12-14L	4	5	3	1	0	0	0	0	0	1	4	4
15-17L	3	4	1	1	0	0	0	0	0	1	2	3
18-20L	4	3	2	1	0	0	0	0	0	1	3	4
21-23L	9	7	5	1	0	0	0	0	1	2	5	7

Visibility Less Than 1/2 mile (800 meters)

HR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
00-02L	4	5	5	2	0	0	0	0	0	1	3	5
03-05L	4	6	7	2	0	1	0	0	1	1	4	5
06-08L	5	7	9	3	1	0	1	1	2	2	4	5
09-11L	3	4	5	2	0	0	0	0	0	1	4	3
12-14L	2	3	2	1	0	0	0	0	0	0	2	1
15-17L	1	3	1	0	0	0	0	0	0	0	1	1
18-20L	2	2	1	1	0	0	0	0	0	0	2	2
21-23L	4	4	3	1	0	0	0	0	0	1	3	3

Table 2b. Percent of Time Visibility is Restricted to Defined Levels by Specified Criteria.
Note: At times, more than one cause of visibility restriction occurs at the same time. This sometimes results in totalled (all causes) percentages greater than 100 percent as each cause is compiled separately.

Astana, Kazakhstan

Visibility Less Than 7 miles (11,000 meters)

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
All HOURS	SMOKE	13	12	9	12	9	4	8	12	15	17	12	11
	HAZE	0	0	0	.	0	0	1	1	0	1	0	0
	DUST	0	0	0	1	2	1	1	1	1	0	0	0
	FOG	10	9	19	11	3	2	4	4	5	7	15	11
	SNOW	50	45	29	7	1	.	0	0	2	13	33	47
	DRIZZLE	1	1	1	1	0	0	0	1	0	1	3	1
	RAIN	0	1	2	5	8	7	8	8	5	7	3	1
	OTHER	28	35	42	65	77	87	78	75	73	54	36	31

Visibility Less Than 3 miles (4,800 meters)

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
ALL HOURS	SMOKE	11	9	5	8	12	3	11	14	23	22	6	10
	HAZE	0	0	0	.	1	.	16	7	3	2	0	0
	DUST	0	0	0	4	7	10	3	2	3	0	.	0
	FOG	20	19	44	48	32	27	34	41	41	26	37	23
	SNOW	68	72	46	26	15	.	2	1	11	39	51	63
	DRIZZLE	1	2	2	4	3	1	1	3	2	4	5	1
	RAIN	0	0	1	9	21	33	17	22	8	7	3	1
	OTHER	3	3	3	6	13	26	16	11	12	4	4	5

Visibility Less Than 1 mile (1,600 meters)

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
ALL HOURS	SMOKE	3	2	2	1	.	.	4	7	3	1	2	2
	HAZE	.	0	1	.	.	.	4	.	.	.	.	.
	DUST	.	.	0	1	.	4	.	.	.	.	.	.
	FOG	25	22	58	59	31	38	29	37	45	51	58	34
	SNOW	72	78	38	28	26	.	7	4	15	39	33	59
	DRIZZLE	1	2	4	2	7	.	.	7	3	1	6	1
	RAIN	0	0	0	2	10	8	7	15	2	2	1	.
	OTHER	3	3	2	10	31	50	50	33	32	7	5	8

Visibility Less Than 1/ 2 mile (800 meters)

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
ALL HOURS	SMOKE	2	1	2	.	.	.	.	6	.	.	.	1
	HAZE	.	.	.	.	.	.	5	.	.	.	.	.
	DUST	.	.	.	.	.	.	.	.	.	.	.	.
	FOG	30	25	64	67	31	53	29	47	50	74	72	49
	SNOW	71	77	32	22	15	.	10	.	24	18	23	51
	DRIZZLE	0	1	4	3	8	.	.	6	6	.	5	.
	RAIN	.	.	0	.	12	7	5	6	3	3	1	.
	OTHER	1	2	2	8	38	40	52	35	18	6	4	6

Wind. Winds prevail out of the southwest all winter with a mean speed from that direction of 13 to 14 knots. The overall wind speed for winds from all directions averages 9 knots all season. Combined with the extreme cold this region experiences, this exposes personnel and equipment to dangerous wind chill conditions. The strongest winds typically occur behind passing cold fronts associated with strong storms. Table 3 shows the percent frequency of occurrence of specific wind directions for Astana. Figure 8 is the January surface wind rose for Astana (Akmola), Kazakhstan.

Table 3. Percent Frequency of Occurrence of Specific Wind Directions for Astana.

Astana (Akmola), Kazakhstan PERCENT FREQUENCY OF OCCURRENCE OF WINDS												
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
N	1	1	1	3	4	6	8	7	3	2	1	1
NNE	1	2	3	5	5	5	8	7	4	3	2	1
NE	4	6	7	6	7	7	10	8	5	4	4	3
ENE	5	8	6	6	6	7	8	7	5	5	4	3
E	5	6	7	9	7	8	7	7	7	6	4	4
ESE	3	3	4	5	5	5	5	4	5	4	4	4
SE	6	6	6	6	6	5	5	5	6	5	6	7
SSE	7	7	6	4	5	4	3	4	5	5	7	8
S	15	13	11	7	7	6	4	6	7	10	11	15
SSW	14	12	9	7	6	5	4	4	6	9	9	14
SW	16	12	11	8	8	6	4	5	9	13	14	15
WSW	10	10	11	8	9	7	5	5	9	12	12	11
W	6	5	9	11	10	10	8	8	11	12	10	7
WNW	2	2	3	5	5	7	6	6	6	4	3	2
NW	1	1	2	4	4	5	6	6	5	3	2	1
NNW	0	1	1	3	3	4	5	4	3	2	1	0
VRBL	0	0	0	0	0	0	0	0	0	0	0	0
CALM	4	4	4	3	3	4	5	5	5	4	3	4

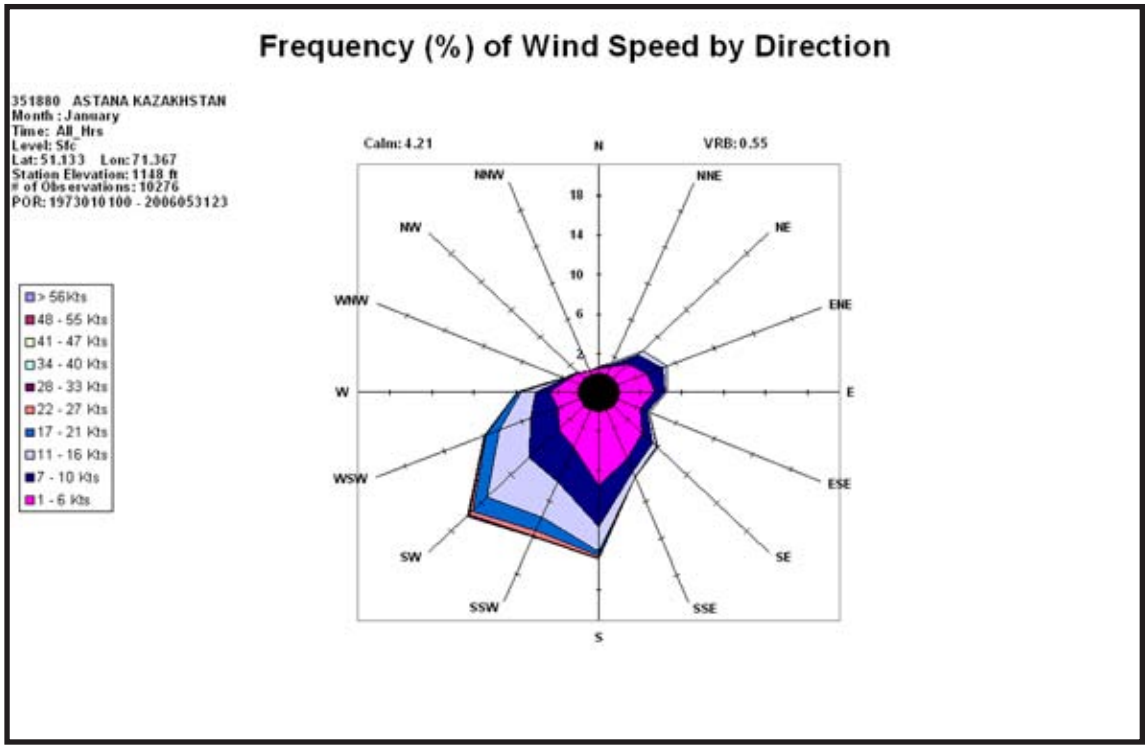

Figure 8. January Surface Wind Rose for Astana (Akmola), Kazakhstan.

Precipitation. Snow is the main form of precipitation from November through March. Snowfall is typically steady and light and once down, snow remains on the ground. A snow event lasts an average of 12-21 hours. Winds during measurable snowfalls are from the southwest more than 50 percent of the time and from the northeast about 30 percent of the time. The maximum mean depth of snow at any point in winter is 6 inches (15 cm) (NIS 26, 1973). Depending on the quality of the snow, cover varies widely. Light, dry snow will be blown around considerably and drifting makes snow cover deep in some areas and leaves the ground bare in others. Wetter snow that has time to form a surface crust before winds blow hard is more uniform in depth.

Table 4. Winter Precipitation Statistics for Astana.

Winter Precipitation	December	January	February	March
Mean Monthly Precipitation	0.9 inch (23 mm)	0.6 inch (15 mm)	0.5 inch (13 mm)	0.6 inch (15 mm)
Extreme Monthly Precipitation	2.2 inches (56 mm)	1.2 inch (30 mm)	0.9 inch (23 mm)	1.6 inch (41 mm)
Mean Precipitation Days	15	13	11	10
Mean Snow Days	15	13	11	10
Mean Monthly days with Snow Depth GTE 1 inch (2.5 cm)	15	17	11	13
Mean Thunderstorm Days	LT 1	LT 1	LT 1	LT 1

Rain is uncommon during winter, but can occur when deep storms in the south advect warmer air into the region. Freezing rain is more likely than rain with these deep storms because the warmer air overrides cold surface air. Rare winter thunderstorms occur with strong lows that pass through the region. These thunderstorms can have gusty winds and moderate snow showers. They are not likely to be severe. Table 4 provides the winter precipitation statistics for Astana.

Table 5. Winter Temperature Statistics for Astana.

Winter Temperatures	December	January	February	March
Mean High Temperature	14F (-10)	9F (-13C)	10F (-12C)	21F (-6F)
Extreme High Temperature	39F (4C)	43F (6C)	39F (4C)	79F (26C)
Mean Low Temperature	2F (-17C)	-3F (-19C)	-4F (-20C)	6F (-14C)
Extreme Low Temperature	-49F (-45C)	-60F (-51C)	-58F (-50C)	-40F (-40C)
Mean Days Below 32F (0C)	29	30	28	30
Mean Days Below 0F (-18C)	13	18	18	10

Temperatures. Astana is in a region that endures constant cold from November through March and outbreaks of cold conditions in October and April. The deepest cold occurs in January and February, when temperatures often fall below -30F (-34C). The coldest temperatures occur under two conditions. First, when the Asiatic high intensifies, bitterly cold air flows southwestward from the Siberian interior. Second, northwesterly or northerly winds behind passing cold fronts pour arctic air over Astana. The coldest conditions generally occur under clear or nearly clear skies associated with arctic continental air masses from northernmost western Siberia and adjacent arctic frozen waters. In these already extremely cold conditions, any winds significantly increase the danger. Table 5 provides the winter temperature statistics for Astana.

SPRING (APRIL-MAY)

General Weather. Spring is when heating of the Asian landmass breaks down the Asiatic high of winter and begins to form the broad Asiatic low-pressure system of summer. This occurs slowly at first as snow cover inhibits warming, but temperatures rise rapidly once the snow is gone. At the same time, the Azores (North Atlantic) high strengthens and begins to expand northward and eastward to encompass parts of Europe. This serves to close the Mediterranean storm track, so that fewer and fewer storms move across Central Asia from the south (Freeman, et al, 2000, Landsberg, 1974, NIS 26, 1973).

Even as the southern storm tracks across the Mediterranean close, the northern tracks across northern Europe become more active. Lows move across Russia and their fronts sweep across the Astana region fairly regularly. Cold air that pours down into Kazakhstan behind cold fronts is responsible for the cold air outbreaks that can still bring severe cold to Astana as late as mid April. Strong, shifting winds, brief periods of overcast skies, and showers (rain or snow) accompany these fronts (Freeman, et al, 2000, Landsberg, 1974, NIS 26, 1973). Figure 9 shows the March through May storm tracks in the region.

By late spring, highs out of the Mediterranean bring warm, fair conditions. Cold migratory highs from the northwest behind cold fronts associated with storm systems to the north bring gusty winds and cold temperatures to Astana for a day or two at a time. Air masses from the northwest are often unstable and moist enough for afternoon cumulus to form in the summer.

Once the snow cover is gone and temperatures warm more rapidly, the environment becomes more unstable. With snow melt contributing to rivers, lakes, ponds and streams, afternoon convection and convection associated with passing frontal systems begin to occur. Steady rain and snow give way to rain showers and thunderstorms (convection). April through July is the period of maximum precipitation for the year because of this showery rainfall, even though rain events are shorter. This is because rain showers and thunderstorms produce heavier rain over smaller areas. It is common for much of the monthly rainfall to occur in only two or three events. Because of the limited areal extent of most shower events, rainfall accumulations vary from place to place and year to year. It is even possible for one side of Astana to get rain from a shower while the other side remains dry (Freeman, et al, 2000, Landsberg, 1974, NIS 26, 1973).

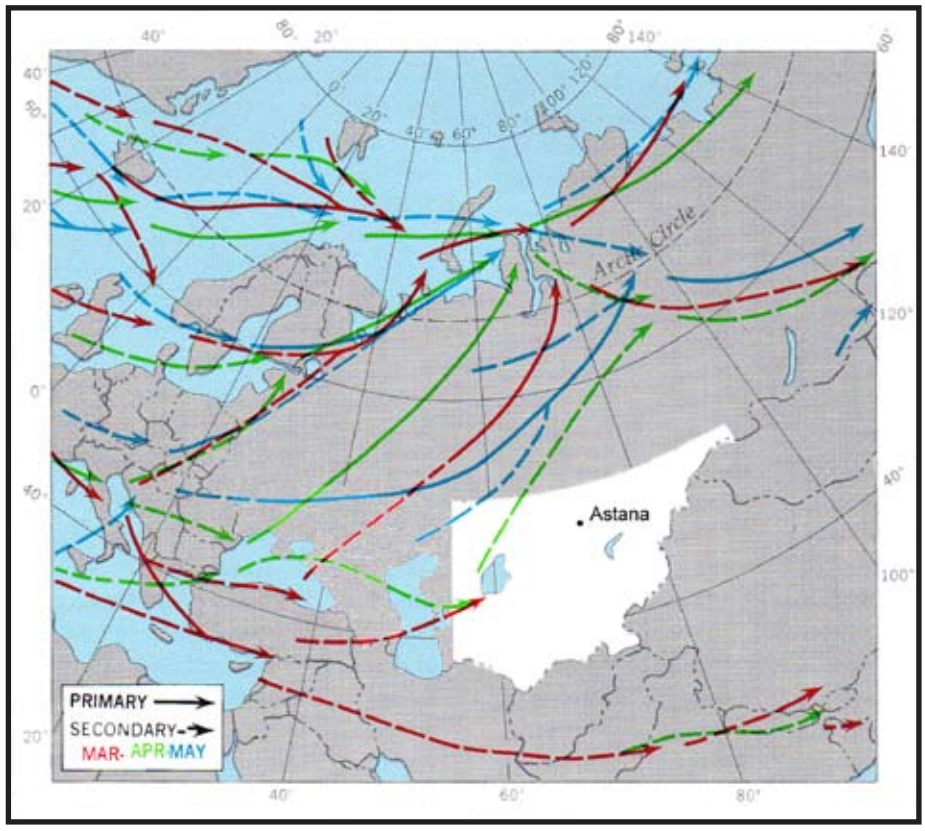

Figure 9. Storm Tracks for March through May.

Sky Cover. Cloud cover gradually changes over from stable types to unstable types as temperatures warm and fewer storms move through the area. April cloud cover is largely similar to that of late winter (multiple layers of stratiform clouds), but May cover is more summer-like, with cumulus and stratocumulus predominating. Overall cloud cover averages broken in both months. In April, ceilings occur at roughly the same frequency at all times of the day. In May, this changes and ceilings occur more frequently in the afternoon and evening than during the rest of the day. Cloudless days remain few but periods without ceilings occur as much as 70 percent of the time overnight and 40 to 60 percent of the time during the day. Table 1 shows the spring percent frequency of occurrence of ceilings at specified levels and times for the full year.

Visibility. Snow becomes far less important as a cause of restricted visibility by early April, although it will cause problems whenever it occurs. Fog is also less of a problem in spring and summer than in winter and fall. This is because conditions are less stable and daytime heating helps dry out the environment. Smoke, pollution and dry haze are the main causes of restricted visibility. Table 2a shows the percent frequency of occurrence for visibility at defined restrictions and times for the whole year. Table 2b shows the percent of time visibility is restricted to defined levels by specified criteria for the whole year.

Wind. The prevailing wind comes from the west at a mean speed of 11 knots in both months. The overall wind speed for all directions is 9 knots. There is only a slight tendency toward westerly winds. Winds from all directions occur almost as often. The strongest winds still occur behind strong cold fronts but thunderstorm down rush gusts can also produce high wind speeds. Evaporative cooling of precipitation (virga) from high based thunderstorms can produce strong down rush gusts and turbulence. Table 3 shows the percent frequency of occurrence of specified wind directions for Astana. Figure 10 is the April surface wind rose for Astana (Akmola), Kazakhstan.

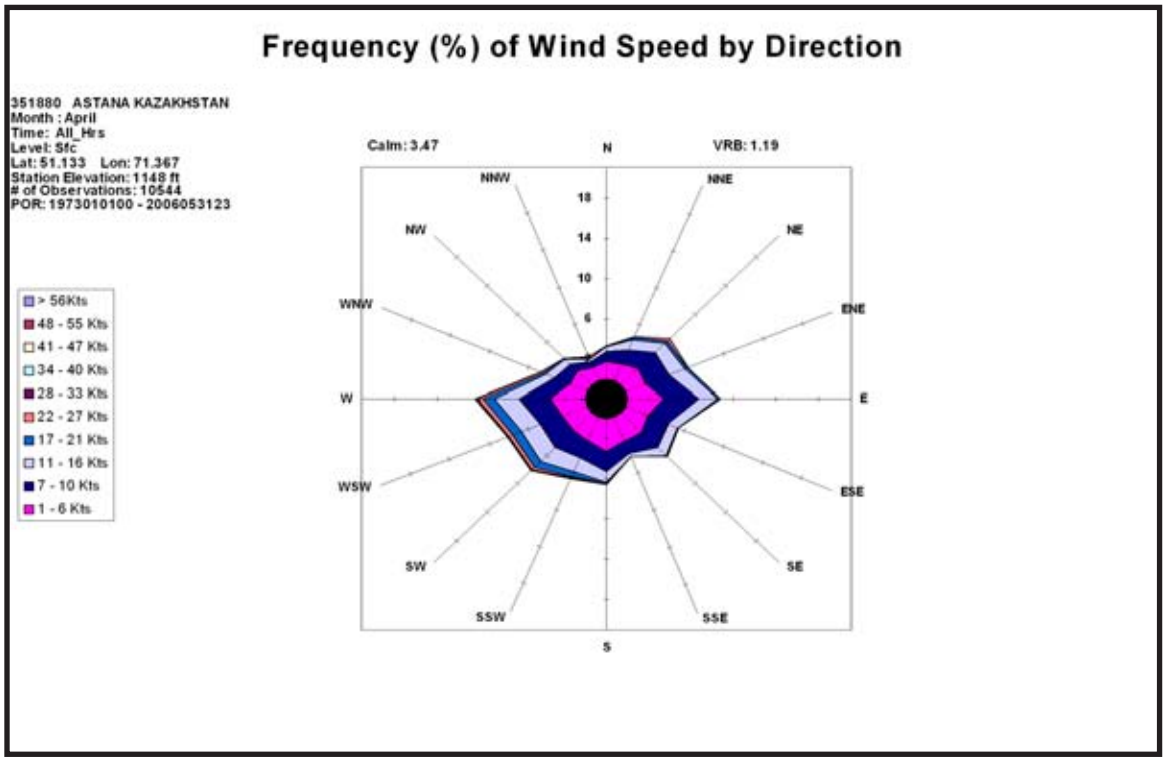

Figure 10. April Surface Wind Rose for Astana (Akmola), Kazakhstan.

Precipitation. Snow tapers off sharply in March. It is still possible through the end of the April, but does not typically occur after the first few days of the month. Accumulations are generally low. Steady precipitation events such as snow or rain give way to the rain showers and isolated thunderstorms that predominate by May. Spring thunderstorms may bring brief, light to moderate rain showers, gusty winds, and occasional hail. Because of their smaller areal extent and shorter lifespan, showery rain events tend to be more hit or miss. Some areas may get precipitation while others nearby remain dry. Also, the whole month's rainfall may occur in only a few brief events. Record monthly rainfall amounts are still quite low in this dry area and individual rain events are typically responsible for most of the heaviest accumulations. Table 6 provides the spring precipitation statistics for Astana.

Temperatures. Temperatures warm slowly at first, and then more rapidly once the snow on the ground disappears. Extreme cold outbreaks can still occur through mid April and subfreezing temperatures remain common throughout the season. The coldest temperatures continue to occur behind passing cold fronts associated with lows that pass well to the north. The last frost of the season typically occurs before the end of April. Table 7 provides the spring temperature statistics for Astana.

Table 6. Spring Precipitation Statistics for Astana.

Spring Precipitation	April	May
Mean Monthly Precipitation	1.1 inch (28 mm)	1.3 inch (33 mm)
Extreme Monthly Precipitation	2.5 inches (64 mm)	2.1 inches (53 mm)
Mean Precipitation Days	8	9
Mean Snow Days	4	1
Mean Days with Snow Cover GTE 1 inch (2.5 cm)	18	1
Mean Thunderstorm Days	LT 1	LT 1

Table 7. Spring Temperature Statistics for Astana.

Spring Temperatures	April	May
Mean High Temperature	46F (8C)	64F (18C)
Extreme High Temperature	84F (29C)	97F (36C)
Mean Days Above 90F (32C)	0	LT 1
Mean Low Temperature	30F (-1C)	44F (7C)
Extreme Low Temperature	-18F (-28C)	12F (-11C)
Mean Days Below 32F (0C)	16	3
Mean Days Below 0F (-18C)	LT 1	0

SUMMER (JUNE-SEPTEMBER)

General Weather. Heating of the Asian landmass produces the broad Asiatic low-pressure system. The Asiatic low, the summer counterpart to the Asiatic high, influences the climate from May to August and reaches peak intensity in July and August. In summer, this low often connects in an elongated trough to other persistent lows from Asia to Africa. These lows include heat lows over Saudi Arabia and Iran, and a low over of northeastern Siberia. The weather with this low is usually hot and dry (Freeman, et al, 2000, Landsberg, 1974, NIS 26, 1973). Figure 11 shows the mean sea-level pressure and generalized wind flow for July.

Lows from the North Atlantic and northern Europe lows stay north of the Astana area, but their associated cold fronts can affect the weather. Summer cold fronts tend to be weak, with the strongest wind gusts with thunderstorms along or ahead of the front. Strong, shifting winds, brief periods of overcast, and showers accompany these fronts. The western end of the polar front extends just to the east of Astana. As a result, Astana is near an area of summer cyclogenesis. Lows that form in this area are weak and disorganized and only become better developed farther east. Migratory lows that occur in the area in summer often have enough moisture to produce cumulus and occasionally cumulonimbus (Freeman, et al, 2000, Landsberg, 1974, NIS 26, 1973). Figure 12 shows the storm tracks for June through August.

Migratory highs affect the area throughout the year. Summer highs out of the Mediterranean bring warm, fair conditions. Arctic highs, while not frequent in summer, do occur and advect cold air from the north and northeast. It is these that are most likely to cause temperatures to drop to or below freezing. The cold snaps do not typically last more than two days at a time with the second day being the coldest. After that, temperatures warm quickly. Strong winds can occur when these highs first move in behind the cold front (Freeman, et al, 2000, Landsberg, 1974, NIS 26, 1973).

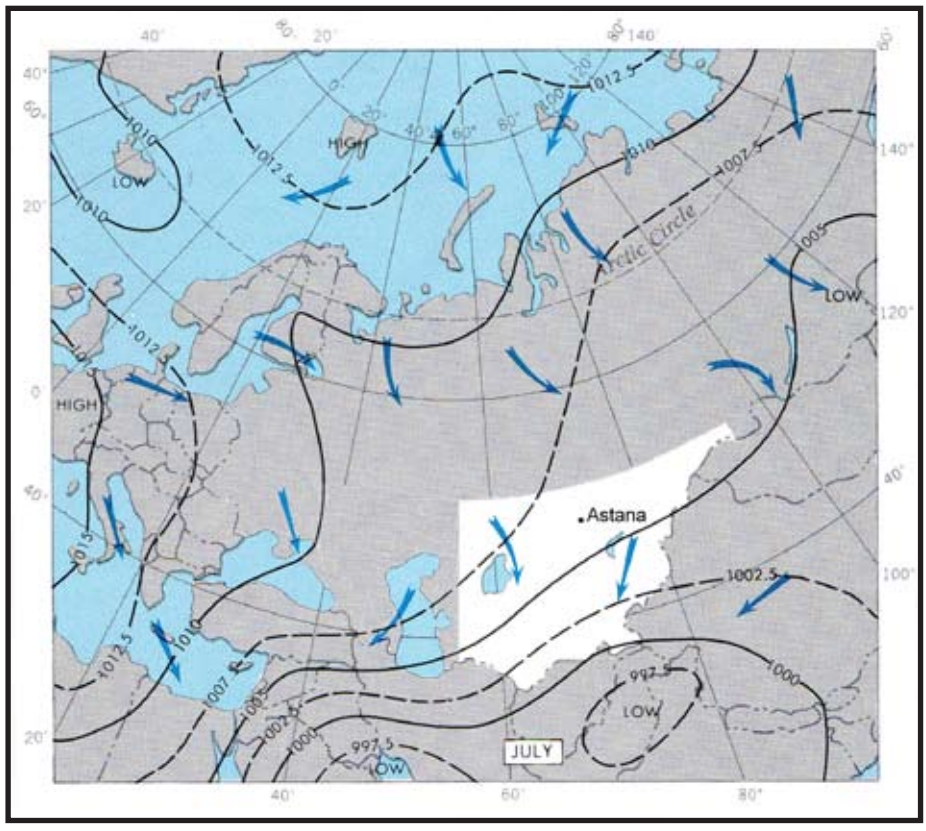

Figure 11. July Mean Sea-Level Pressure and Generalized Wind Flow.

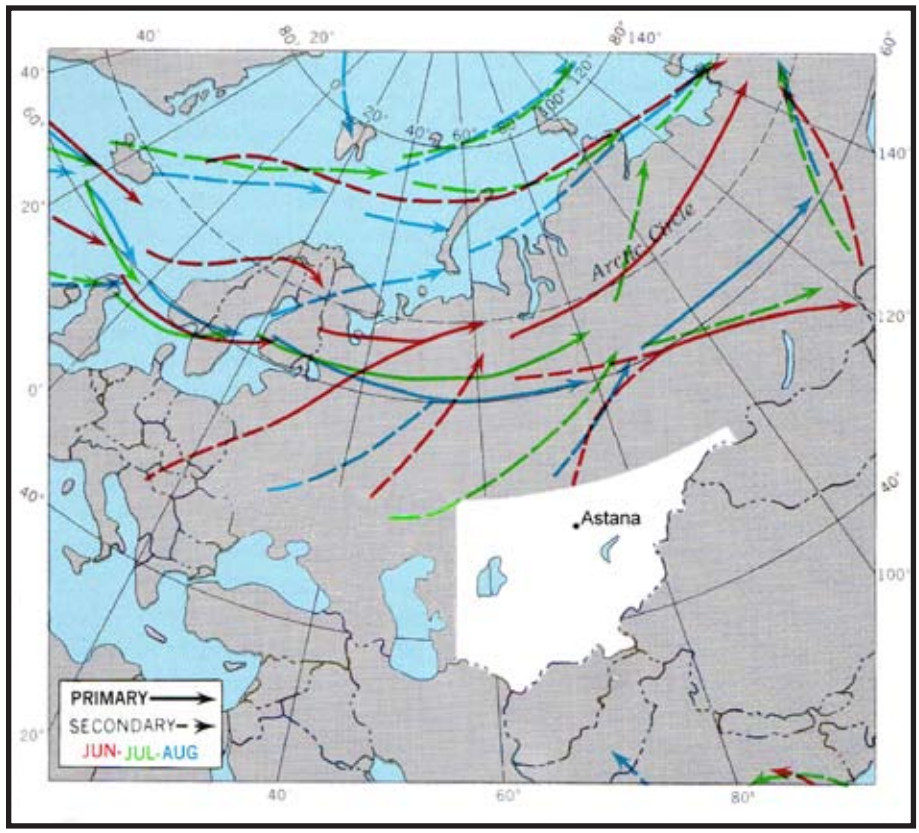

Figure 12. Storm Tracks for June Through August.

Sukhoveis are warm to hot, extremely dry winds that desiccate vegetation in a very short period of time, often within hours of onset. Sukhoveis normally need the formation of a warm upper level ridge over Europe and/or European Russia to occur. This provides subsidence, which contributes to the winds and assures cloudless skies for maximum solar heating. Sukhoveis usually develop within 5 days after a stationary or slow-moving migratory high sets up over the area. Sukhoveis occur most often and are most intense with the tightest pressure gradient on the southwest periphery of these surface highs. The southwestern periphery is where turbulent mixing, necessary for sukhoveis, becomes most intense. The slow movement of the migratory high allows strong solar heating to cause turbulent mixing. Turbulent mixing then causes relative humidity to decrease. Since a dry environment releases heat faster than a moist one, decreased humidity allows even stronger turbulent mixing to occur and sukhoveis intensify. Sukhoveis occur most often in summer, especially after a dry fall followed by a cold, dry winter. The onset of warm, fair weather under an unusually strong Azores (North Atlantic) high over Europe is often a precursor to sukhovei winds at Astana. Sukhovei conditions occasionally occur during outbreaks of arctic air. In these cases, the invading air mass wind and extremely low relative humidity (less than or equal to 10 percent) are the primary elements involved. Winds with sukhoveis average 5-15 knots, with gusts occasionally over 25 knots. Sukhovei winds can carry dust aloft to 5,000-7,000 feet MSL. Inversions that accompany sukhoveis are normally based above 6,000 feet MSL (Freeman, et al, 2000, Landsberg, 1974, NIS 26, 1973).

Sky Cover. Although summer still has scattered to broken ceilings all season, this is when the least cloud cover of the year occurs. Cumuliform clouds predominate and the most ceilings typically occur in the afternoon and evening. Isolated thunderstorms sometimes spread their cirrus canopies over large areas. Low ceilings typically only occur under thunderstorms or large rain showers. Periods without ceilings occur 60 to 70 percent of the time overnight and 40 to 50 percent of the time during the day. Table 1 shows the percent frequency of occurrence of ceilings at specified levels and times for the full year.

Visibility. Summer visibility is typically the best of the year. Pollution is overwhelmingly the main cause of restrictions below 7 miles (11,000 meters), but does not cause reductions much below 5 miles (8,000 meters). Rain, smoke and fog are minor causes and none of these persist for long. If, however, visibility is restricted

below 3 miles (4,800 meters) early morning fog is the cause more often than rain or smoke. Table 2a shows the spring percent frequency of occurrence for visibility at defined restrictions and times for the whole year. Table 2b shows the percent of time visibility is restricted to defined levels by specified criteria for the whole year.

Wind. Summer winds are lighter than at any other time of year and quite variable. Local circulations such as land/lake breezes and country/city breezes alter wind directions and speeds in the immediate area of the terrain features as do weak nocturnal drainage winds into Astana's shallow basin. While the prevailing winds come from the west at 9 to 10 knots in June and September and from the northeast at 8 knots in July and August, the frequency of westerly winds is not much higher than that of any other direction. Thunderstorm down rush gusts are largely responsible for the strongest winds in summer, but an atypically strong cold front can produce high gusts as well. Table 3 shows the percent frequency of occurrence of specified wind directions for Astana. Figure 13 is the July surface wind rose for Astana (Akmola), Kazakhstan.

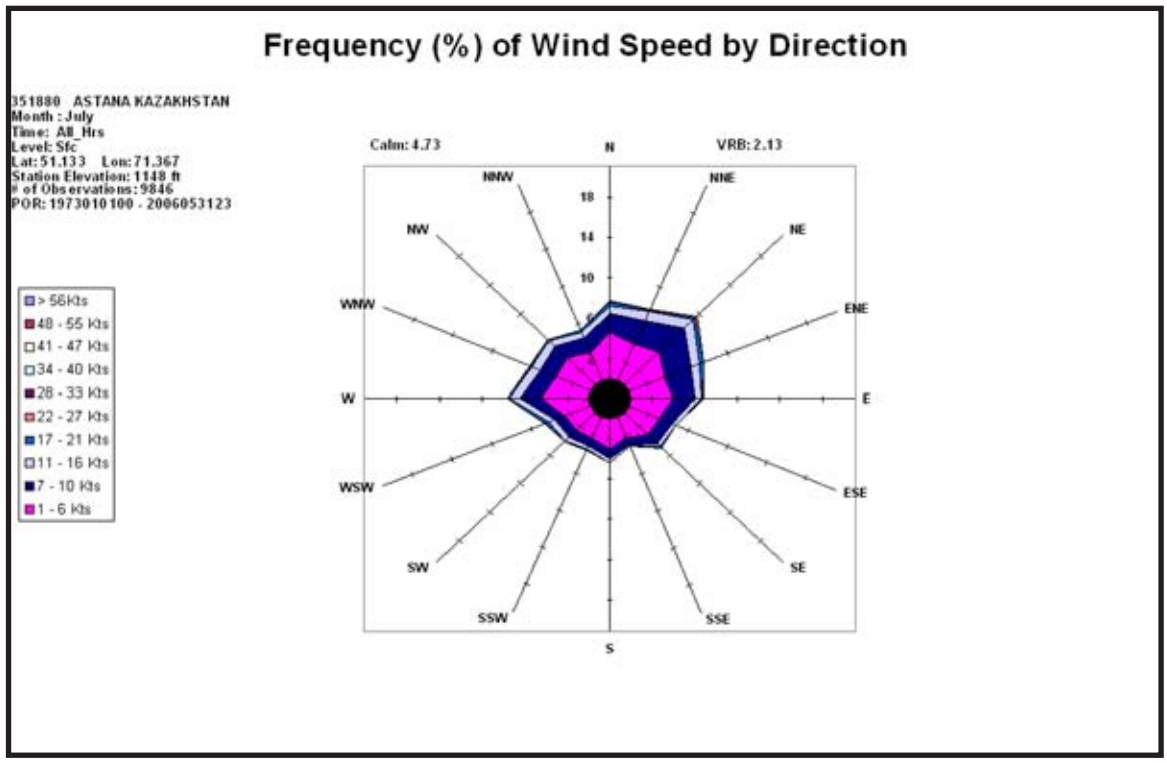

Figure 13. July Surface Wind Rose for Astana (Akmola), Kazakhstan.

Precipitation. The heaviest precipitation events of the year occur in summer afternoon convection. Typical daily rain shower amounts are generally light, but large thunderstorms can produce heavy rainfall. Considerable evaporation occurs due to low relative humidity, but the area lakes and rivers mitigate this somewhat. Thunderstorms may include occasional hail. Table 8 provides the summer precipitation statistics for Astana.

Temperatures. Temperatures are generally only mildly warm in Astana summers, but there are hot spells once or twice a month. Temperatures above 100F (38C) occur in every month of the summer season except September. The highest temperatures occur with sukovei winds and extremely low humidity accompanies these winds. This can create dangerous heat for ground personnel because of dehydration. Table 9 provides the summer temperature statistics for Astana.

Table 8. Summer Precipitation Statistics for Astana.

Summer Precipitation	June	July	August	September
Mean Monthly Precipitation	1.3 inch (33 mm)	1.9 inch (48 mm)	1 inch (25 mm)	0.9 inch (23 mm)
Extreme Monthly Precipitation	2.8 inches (71 mm)	5.8 inches (147 mm)	3 inches (76 mm)	1.5 inch (38 mm)
Mean Precipitation Days	8	9	7	7
Mean Snow Days	0	0	0	1
Mean Thunderstorm Days	5	6	3	1

Table 9. Summer Temperature Statistics for Astana.

Summer Temperatures	June	July	August	September
Mean High Temperature	75F (24C)	78F (26C)	74F (23C)	63F (17C)
Extreme High Temperature	104F (40C)	108F (42C)	102F (39F)	91F (33C)
Mean Days Above 90F (32C)	2	3	1	LT 1
Mean Low Temperature	55F (13C)	59F (15C)	54F (12C)	44F (7C)
Extreme Low Temperature	28F (-2C)	32F (0C)	25F (-4C)	12F (-11C)
Mean Days Below 32F (0C)	LT 1	LT 1	LT 1	3

FALL (OCTOBER-NOVEMBER)

General Weather. The Asiatic low breaks down in fall as temperatures cool and the Asiatic high of winter develops. At the same time, the Azores (North Atlantic) high weakens and shifts to the south and west. This opens the Mediterranean storm tracks and more lows travel farther south. Associated wrap-around cloud cover and precipitation from these southerly lows begin to impact Astana more and more often. The first snows of the cold half of the year occur in October in most years, but September snow is not unknown. The first snow cover that persists typically occurs in November, but is nearly as common in mid to late October (Freeman, et al, 2000, Landsberg, 1974, NIS 26, 1973).

Migratory lows affect the area. While lows do not pass over Astana on a regular basis, their fronts do. Storm systems from the North Atlantic and northern Europe track across Central Asia and Russia all year. These lows stay north of the Astana area, but their fronts and winds can impact the weather here. From November onward, lows from the Mediterranean and Black Seas reach the Astana region. The parent lows do not typically cross Astana, but their associated cloud cover and precipitation do. The actual storm tracks depend on upper flow patterns and the relative strength of the Asiatic high. Much of the precipitation (snow or rain) that occurs in fall and winter comes from these lows. If the centers track west to northwest of the area, Astana will have weather ahead of and with cold fronts for 3-9 hours. Lows that track south of the area usually have occluded fronts. These cause 1-2 days of low cloudiness, reduced visibility, and snow showers (Freeman, et al, 2000, Landsberg, 1974, NIS 26, 1973). Figure 14 shows the storm tracks for September through November.

Migratory highs affect the area throughout the year. Mild, moist air with highs from the west to northwest can bring considerable low and mid-level cloudiness as they move over the cold ground of winter. Arctic highs move in from the north and northeast and can advect in bitterly cold temperatures, dry conditions and strong winds behind the cold front. Cold fronts are the most common weather systems to affect the area from the north. Snow, gusty winds, and much colder temperatures occur behind cold fronts by late in October. Warm fronts occur when lows to the south pass near the area as they move southwest to northeast. They normally produce steady, light precipitation, extensive cloud cover, and relatively warmer temperatures (Freeman, et al, 2000, Landsberg, 1974, NIS 26, 1973).

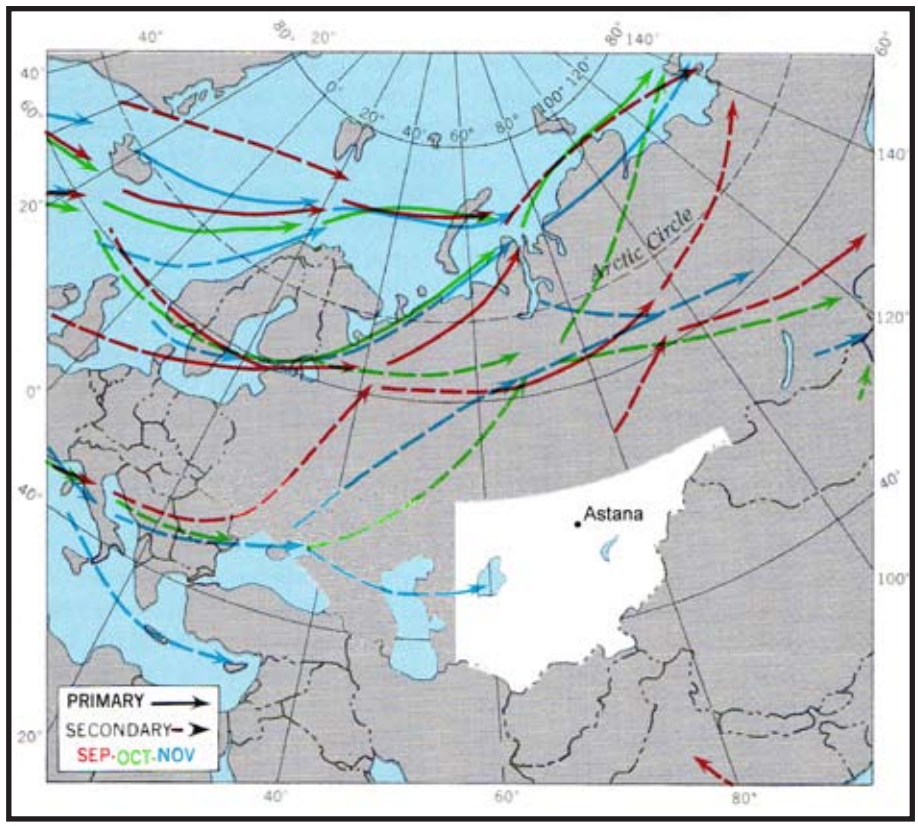

Figure 14. Storm Tracks for September Through November.

Sky Cover. The mean cloud cover is broken in both months, but November typically has more cloud cover than October does. The predominant cloud type changes from cumuliform to multiple stratiform. Low ceilings occur more often as the season progresses. Low pressure systems that begin to move through to the south approach more and more closely as they pass. Cloud cover associated with them reaches Astana more and more often. Periods without ceilings occur 35 to 45 percent of the time at all hours with little to no diurnal variation. Table 1 shows the percent frequency of occurrence of ceilings at specified levels and times for the full year.

Visibility. While pollution continues to be the main cause of visibility restrictions below 7 miles (11,000 meters), fog, smoke, and snow all restrict visibility more and more often as fall progresses. Both snow and fog restrictions nearly double between October and November. Fall is also when farmers burn off field debris in preparation for spring planting. Astana is surrounded by fields and smoke can get heavy at intervals. Fortunately, the winds increase in the fall and smoke is generally cleared away within hours. Table 2a shows the spring percent frequency of occurrence for visibility at defined restrictions and times for the whole year. Table 2b shows the percent of time visibility is restricted to defined levels by specified criteria for the whole year.

Wind. The local winds become less variable during fall as the Asiatic high replaces the Asiatic low of summer. By early October, southwesterly winds at 13 to 14 knots prevail at Astana. The strongest winds are typically associated with cold flow behind fronts associated with migratory storms that pass to the north. The strongest winds usually occur on the day of cold frontal passage. Table 3 shows the percent frequency of occurrence of specified wind directions for Astana. Figure 15 is the October surface wind rose for Astana (Akmola), Kazakhstan.

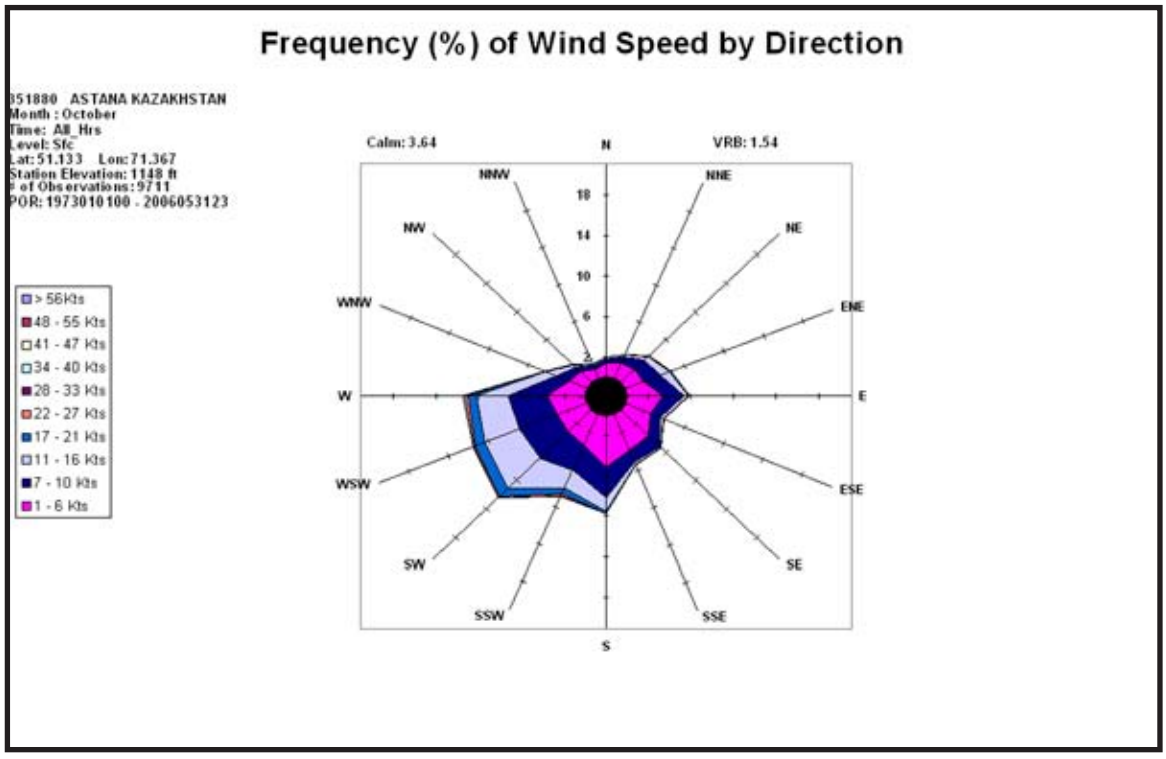

Figure 15. October Surface Wind Rose for Astana (Akmola), Kazakhstan.

Precipitation. Rain showers and thunderstorms that prevailed in summer disappear in fall as temperatures cool and more stable conditions return to the region. Most precipitation is light. Rain is more common in October, but by November, steady, light snow is typically the only form of precipitation. Measurable amounts of snow occur 3-7 days per month. The average snowfall lasts 12-21 hours. Rain can still occur in November with deep storms that advect warm air into the region from the south, but freezing rain is more likely under these conditions. Rare fall thunderstorms occur with cold fronts associated with strong lows that pass through north of the region. These thunderstorms can have gusty winds and moderate snow showers. They are not likely to be severe. Table 10 provides the fall precipitation statistics for Astana.

Temperatures. Temperatures cool rapidly in fall, especially once there is snow on the ground. Cold air outbreaks can bring extremely cold conditions to Astana as early as the first week in October. Day-to-day temperatures fluctuate by as much as 20-30 Fahrenheit (11-17 Celsius) degrees with passing storm systems. Northerly winds (northwest through northeast) drop temperatures rapidly at onset. Table 11 provides the fall temperature statistics for Astana.

Table 10. Fall Precipitation Statistics for Astana.

Fall Precipitation	October	November
Mean Monthly Precipitation	1.2 inch (30 mm)	1 inch (25 mm)
Extreme Monthly Precipitation	2.8 inches (71 mm)	2.1 inches (53 mm)
Mean Precipitation Days	11	13
Mean Snow Days	6	13
Mean Days with Snow Depth GTE 1 inch (2.5 cm)	3	15
Mean Thunderstorm Days	LT 1	LT 1

Table 11. Fall Temperature Statistics for Astana.

Fall Temperatures	October	November
Mean High Temperature	46F (8C)	25F (-4C)
Extreme High Temperature	81F (27C)	63F (17C)
Mean Low Temperature	31F (-1C)	14F (-10C)
Extreme Low Temperature	-15F (-26C)	-44F (-42C)
Mean Days Below 32F (0C)	18	28
Mean Days Below 0F (-18C)	LT 1	6

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